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ABSTRACT

The purposes of this study were to determine the modality strengths of each child in grades 1 to 5 at Butcher Children's School, Emporia, Kansas, and to ascertain whether modality can be linked to grade level, to reading achievement, or to sex. For identifying modality strength, the Swassing-Barbe Modality Index (SBMI), a matching-to-sample task, was administered to the 101 children enrolled in grades 1 to 5 at Butcher Children's School. Stimulus shapes (e.g., hearts, circles, triangles, and squares) were presented to subjects three times -- visually, auditorially, and kinesthetically. Following these presentations, subjects were asked to reproduce the same sequence from memory. Each subject's performance on the SBMI was then classified according to the following modality strengths: visual, auditory, kinesthetic, visual-auditory mixed (V-A), visual-kinesthetic mixed (V-K), auditory-kinesthetic mixed (A-K), and none (V-A-K). Reading achievement of children in grades 2 to 5 was measured by the Gates MacGinitie Reading Tests, Forms B, C, and D. Results revealed that 46 per cent of the subjects showed strength in the visual modality, 16 per cent showed strength in the auditory modality, 12 per cent in V-A, 11 per cent in V-K, and 6 per cent in the kinesthetic modality. It was also found that modality strength is independent of grade level, reading achievement, or sex. A complete list of modality strengths for all the individuals participating in the study is appended. (Author/MP)

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A STUDY OF MODALITY
STRENGTHS AMONG THE CHILDREN
ENROLLED IN BUTCHER CHILDREN'S SCHOOL
EMPORIA STATE UNIVERSITY
1980-81

12/20 apr

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A STUDY OF MODALITY STRENGTHS AMONG THE CHILDREN ENROLLED
IN BUTCHER CHILDREN'S SCHOOL
EMPORIA STATE UNIVERSITY
1980-81

This is a study investigating learning modality strengths among children enrolled in Butcher Children's School. The purposes of the study were to determine the modality strength of each child in grades 1-5 at Butcher and to ascertain whether modality can be linked to grade level, to reading achievement, or to sex.

For identifying modality strength, the Zaner-Bloser Modality Kit by Swassing and Barbe was used. Tests in visual, auditory, and kinesthetic modes were administered to each child. Results of the Gates-MacGinitie Reading Tests administered in April were also used in the statistical analysis. The data were tested by using the Chi-square goodness-of-fit test.

Modality strengths of the Butcher population as identified by the study were as follows: visual, 46%; auditory, 16% kinesthetic, 6%; visual-auditory mix, 12%; visual-kinesthetic mix, 11%; auditory-kinesthetic mix, 5%; none, 4%. It does not appear from this study that, at least for the BSC population, grade level, reading achievement, or sex can be used as a predictor of modality strength, or vice-versa. As a result of the study the investigators feel that it will be possible to move into other types of investigations concerning learning styles perhaps testing the effects of matched single-modal instruction, mismatched single modal instruction, mixed modal instruction, etc. Some effort may also be made to correlate the modality strengths of Swassing-Barbe with the modality preferences identified by Dunn and Dunn.

From this study, no attempt was made to make inferences about populations other than that of BCS. However, it would appear that the premise held by some that most early learners are auditory in strength/preference may be in question.

The question still remains as to how much emphasis educators should place upon attempting to strengthen weak modal areas as opposed to teaching primarily through the strongest mode.

Purpose of the Study

The primary aims of this study were (1) to determine the modality strength for each student at Butcher School, (2) to ascertain if the students of the school as a whole display a significant modality strength, and (3) to ascertain whether modality strength is independent of reading ability.

These aims are of obvious value for us at a time when the study of modality strengths is of high concern and when some believe that a difference of about five percentage points between modality strengths corresponds to an educationally relevant difference. (Swassing-Barbe)

While this study did not address the question of the use of modality strength in instruction--that is, whether one should teach to the child's modality strength or to his deficit or whether one should use some type of combined approach--it did obtain the basic information needed regarding the modality strengths of the Butcher School population in case such a question is investigated as a separate study.

It is possible that modality strength and the methods of teaching reading do not interact significantly and that we should devote our attention to the tasks to be learned rather than to the strengths and weaknesses of the learner. Tarver (1978). Indeed some investigations have indicated that auditory based methods are superior for all types of learners and that auditory learners tended to perform better than visual learners regardless of the modality through which the material was presented. Newcomer and Goodman (1975). It is possible for a laboratory school to add to the investigations, and to provide evidence of support or of denial for such claims.

The first steps in that direction were thus taken in this study. Modality strengths were identified. For each child at the school, this added bit of information is available to go along with such other measurements and characteristics as mental age, sex, chronological age, I.Q. reading ability, etc.

With this totality of information, a decision can be made as to whether or not it is feasible to pursue further investigations with respect to modality strengths. For example, the reading ability of each student as indicated by his total Extended Scale Scores (ESS) is an ability reached through instruction that had not been centered about his particular modality strength. In other words, his strength had not been ascertained in advance. Now, however, the investigators are in a position to select control groups and to note increases in ESS scores when modality based methods are used as compared to those changes when modality based methods are not used.

In the process of carrying out the aims of this study, other secondary questions were addressed: Is there a modality strength for grades 2-5, and if so, is it the same as for the school as a whole? Is modality strength independent of grade level, of sex, of reading ability? Is there any significant relationship between modality strengths for a few students at Butcher who can be identified as having reading difficulties?

In summary, this study was aimed at obtaining information about the population of Butcher School. It was not an investigation of a sample aimed at making some inference about some larger population. It was a study needed by the personnel of a laboratory school interested in the possibilities of modality-based instruction.

Survey of the Literature

A review of the literature revealed that there is a difference of opinion among researchers in regard to the significance of modality preferences. Waugh (1973) administered the Illinois Test of Psycholinguistic Abilities (ITPA) to 166 second graders who were classified as auditory or visual learners on the basis of discrepancies in individual test profiles. She states that the idea that groups of children have a preferred modality that facilitates recall and recognition of words was not supported in her study. She believes that an important consideration for special educators is to question themselves about the usefulness of a specified activity. In another article (1975), she relates that the ITPA is not a useful tool for assessing modality preference, and although it is well constructed, it is not a psycholinguistic test since it does not reflect current knowledge of the development of natural language systems. Furthermore, Waugh (1975) says that attempts to match instructional methods to preferred modality or to strengths or weaknesses in perception have not been effective, and even though studies are cited which show that children who have had extensive individualized instruction have improved, there is no reason to make generalizations to larger groups of children. Such cases, according to Waugh, simply indicate the flexibility of human beings and offer hope for educating exceptional children.

Newcomer and Goodman (1972) administered the ITPA and 18 additional modality tests to a group of 167 fourth graders. Fifty-seven students who fell below established criteria were randomly assigned to eight small instructional groups, and specialized techniques were used for instruction. The implications from this study are that when dealing with fourth-grade

students, teachers need not be concerned with matching the channel of academic instruction with student modality or preferences. Visual presentation of materials should take precedence over other modalities since children supply their own auditory associations.

Tarver and Dawson (1978) in a review of 15 studies investigating the interaction between perceptual modality preference and method of teaching reading found that most educators recommend some type of combined approach, with differing degrees of emphasis on teaching to the strength or deficiency, or an intersensory integration. Wepman said that educators needed to capitalize on the modality of preference by using a visual approach to the teaching of reading if the child exhibits auditory perceptual deficits and recommended training the underdeveloped or impaired pathway separately so that the two channels could be brought together at an opportune time to complement each other. Other educators recommended teaching to the strengths in order to develop positive attitudes. There were advocates of a multisensory approach so that all children would have an opportunity to acquire information through their strongest modality, while intersensory integration could be facilitated. Others cautioned against this because of the possibility of overloading the central nervous system. An aptitude-treatment interaction design was recommended to demonstrate a disordinal interaction between modality preference and method of instruction. By using this kind of design, it was suggested that two questions could be investigated: (1) Does modality preference affect reading achievement regardless of method? (2) Does method of teaching reading affect reading achievement regardless of preferred modality? In regard to the modality-matching issue, in 15 published studies mentioned by Tarver and Dawson it was suggested that first graders who have not been exposed previously to methods of teaching reading in the classroom should be

considered for experiments of this nature, since children have a tendency to employ a particular method of learning to read if they have already been exposed to a particular approach. Further research was recommended to determine the proportion of exceptional children, mainly learning disabled, exhibiting a modality preference. The review revealed that more visual learners may be found within a lower I.Q. range, while auditory learners, as far as percentages were concerned, may remain essentially the same across I.Q. ranges. Others found that I.Q. did not interact with modality preference. The conclusion that reading should be taught through the strong modality was not warranted on the basis of the review, and it was indicated that modality preference and method of teaching reading do not interact significantly when one is concerned with actual methods of teaching reading and measures of reading achievement, rather than listening tasks and measures of recall or recognition. One author found that auditory discrimination made a significant contribution to reading achievement at both first and third grades regardless of the method of teaching, while visual perception did not. Finally, it was suggested that time should be devoted to investigating the requirements of the reading task at the various stages of learning to read, and that from such information a scientifically validated sequence of reading skills may be developed which would promote better individualization of instruction based on rates of progression through those skills rather than on differences in perceptual functioning.

Meehon (1974) suggested An Informal Modality Inventory for the classroom teacher. She contended that such an inventory would be useful to teachers in their direct observation powers as they become better informed in the area of modalities. As a result, intelligent decisions can be made

in selecting valuable and reliable activities. Teachers could base their judgments on activities set up in Aids to Psycholinguistic Teaching. If a student does not function at the 90 percent proficiency level according to grade placement, he would be given practice until he reaches the proficiency level. The Informal Modality Inventory was designed to be used for students of normal to superior intelligence who were not succeeding by fourth grade. No effort was made to discuss the value of whether learning modes were important to educational success because materials which have been written in this area are neither conclusive nor definitive.

In a study which included a stratified, proportionate, random sample of 99 from a total population of 591 first-grade pupils in five Dade County public schools, Gurucharri (1973) investigated the relationship between haptic functioning and first-grade reading achievement, to determine whether there were significant differences in haptic functioning among sub-groups of first-grade subjects cross-partitioned according to socio-economic level, sex, and risk of failure. She found that certain haptic skills have a significant relationship to beginning reading achievement. Findings have implications for testing, teaching, remediation, and preparation or selection of perceptual training materials. Concern about haptic discrimination ability may add to the present understanding of modality functioning. For further research in this area, the development of a standardized valid and reliable diagnostic battery of tests in a modality was suggested. Such an effort has received minimum attention in research.

A study by Gilley, French and Russell (1976) identified a set of six theoretical styles of learning which have as their base the individual's preferential sensory input mode. A multi-modal paired associates learning test was used to determine the preferred modality of a population of

24 third-grade children from five Knoxville, Tennessee city elementary schools. Subjects previously classified as high achievers or low achievers were administered the test. An analysis of variance was used to find that children did receive and process information with different degrees of efficiency; significant differences existed between children of different achievement levels; significant differences existed between children of similar achievement levels; the variable of sex was found to be nonsignificant; significant differences existed between modes of information input, and each child possessed a different hierarchical alignment of preferred sensory input modes. The assumption upon which the study was based, i.e., that individuals receive and process information differently, was substantiated. Among all subjects, high and low achievers, the most effective means of information input was through the haptic modality. The paper refuted the assumption of commonality of learning style and the commonality of style within an achievement level. It suggested (1) that a child does not necessarily share the same personal learning style with all other children found to be within his/her achievement range, and (2) even though educators for too long identified children as slow or gifted based upon their performance on standardized achievement tests, "slowness" or "giftedness" may be more of a manifestation of learning style than one of achievement or ability. The authors suggested that if we assume that successful experience in the world depends upon an integrated multi-sensory approach to learning, then educators are faced with helping the child to learn in modalities other than his dominant one. Further research is needed to answer the following questions:

Does an individual maintain dominance in a learning style (or specific combination of learning styles) throughout life? Do different styles achieve dominance at different stages of human development? How does the individual's modality prefer-

ence correspond with his modality utilization? If learner styles differ, do teaching styles also differ as a reflection of the teacher's learning style?

Would children perform more effectively working with a teacher whose learning style is compatible?

Would it be helpful for a learner to work with other learners whose styles are similar or with those whose styles are different?

Is home environment a determining factor in the development of learning styles?

Why do children from a specific cultural background perform well in one sensory modality and poorly in another?

Shall the intersections or correlations of the individual's approach in several dimensions be located?

Barbe and Milone (1981) state that a modality strength is not the same as a modality preference. According to them, a modality strength implies superior functioning in one or more perceptual channels, and a test like the Learning Methods Test (Mills, 1970) can be used to assess it. A modality preference, by their definition, is simply a preference. In a study on 1000 southern school children, they found (1) that students vary with respect to their modality strengths, (2) modality strength is not a fixed characteristic, and (3) there is no difference between the modality characteristics of boys and girls. Handedness and modality strengths did not seem to be related, and race and modality strengths were independent. The findings suggested that minority children who are exposed continually to the majority culture have modality strengths similar to those of their majority peers. Another finding indicated that there is an interaction between student and teacher modality strengths. The implications of the Barbe and Milone study supported the contention that modality strengths should be considered in instructional planning and also in selecting or developing media and materials and designing the physical plant. Teachers and supervisory personnel should be aware

of their own modality strengths. Teachers should also realize that they probably teach the way they learn best, and that many students have other modality strengths. Supervisors should be cognizant of the fact that their perceptions of a teacher's effectiveness may be clouded by their own modality strengths. Finally, they suggest further research in the following areas:

1. To determine what materials work best with pupils of a particular modality strength.
2. To determine whether grouping students or matching students and teachers by modality are worthwhile practices.
3. To determine the relationship between modality strength and achievement.
4. To determine the effect of the school and home environment on development of modality strengths.

Donovan and Austin (1978), in a study of 107 first grade students from a multi-ethnic, multilingual, multicultural, economically disadvantaged Hawaiian community, found that pupils whose modality preferences were congruent with the primary instructional focus of initial reading progress achieved significantly higher scores on all measures of initial reading behavior than did pupils whose modality preferences were not congruent with the instructional focus. Experimental placement was more effective with teachers of greater competency. This experimental study was preceded by a longitudinal study which was evaluated in effectiveness by the Gates MacGinitie Silent Reading Tests. Consideration of the student's modality preference prior to initial reading instruction made a difference in later reading achievement.

Procedure

During the 1980-81 school year, the Swassing-Barbe Modality Index was administered to the total school population of Butcher Children's School. The total population consisted of 101 children. The Barbe-Swassing Modality Index is a matching-to-sample task. Stimulus shapes, e.g., hearts, circles, triangles, and squares, are presented to the examinee three times--visually, auditorily, and kinesthetically. There are potentially nine stimulus items in each modality subtest. The first item consists of a single circle which is used as a sample item and included in the scoring. The last item which is rather complex consists of nine items--square, triangle, heart, circle, square, square, circle, heart, and triangle. When the stimuli are presented to the examinee, he must reproduce the sequence from memory visually, auditorily and kinesthetically. All shapes which are presented in each modality are of the same size, color, and texture. No sensory cues are given except those which are necessary for proper administration of the Index. Administration time for the Swassing-Barbe Index is approximately 20 minutes per student. The standardized instrument requires no certification or extensive training, identifies modality strengths rather than deficits, produces a profile of the relative modality strengths of each subject, and has applications both in the classroom and in research settings.

The same examiner, a graduate assistant, trained by a professor in the Division of Administration, Curriculum and Instruction, administered the Index to each student. The responses of the total school population were classified into a table by grade levels 1-5 according to the following modality strengths: visual, auditory, kinesthetic, mixed (V-A), mixed (V-K) mixed (A-K), and none (V-A-K). The data were then grouped showing a comparison of the above modality strengths for grades 2 and 3, 4 and 5, and 2-5, respectively.

The Gates MacGinitie Reading Tests were given to grades 2-5 (Form B, C, D), respectively, by the regular classroom teachers. The total Extended Scale Scores (ESS) were used to test the last three hypotheses related to modality strength and reading ability.

The Chi-square goodness-of-fit test was used to test the following Null hypotheses:

There is no significant modality strength displayed by the total population of grades 1-5.

There is no significant modality strength displayed by grades 2-5.

The modality strenghts displayed by grades 2-5 are not significantly different from those displayed by grades 1-5.

The modality strengths displayed by the population of grades 2-5 are independent of whether lower grade (grades 2, 3) or upper grade (grades 4, 5).

In grades 2-5, the modality strength is independent of sex.

Modality preference in grades 2-5 is independent of level of reading ability.

Modality preference in grades 2-5 is independent of level of reading ability (in terms of upper scores, middle scores and lower scores).

When every student of grades 2-5 is classified a type I if his visual percentage is at least five points higher than his auditory percentage, a type II if his visual percentage is at least five points lower than his auditory percentage, and a type III otherwise, then his classification is independent of reading ability as measured by total Extended Scale Scores on the Gates MacGinitie Reading Test.

Findings

Tabulation of the modality strengths for the various grades as well as for the total school population are shown here.

	TOTAL SCHOOL POPULATION											
MODALITY	Grade 1		Grade 2		Grade 3		Grade 4		Grade 5		TOTAL	
	#	%	#	%	#	%	#	%	#	%	#	%
VISUAL	9	39	12	54.5	7	41	13	54	6	40	47	46
AUDITORY	5	22	5	23	3	17	2	8	1	6.5	16	16
KINESTHETIC	1	4	2	9	2	12	0	0	1	6.5	6	6
MIXED (V-A)	4	17	1	4.5	2	12	4	17	1	6.5	12	12
MIXED (V-K)	2	9	1	4.5	0	0	4	17	4	26.5	11	11
MIXED (A-K)	2	9	1	4.5	1	6	0	0	1	6.5	5	5
NONE (V-A-K)	0	0	0	0	2	12	1	4	1	6.5	4	4
TOTAL	23	100%	22	100%	17	100%	24	100%	15	99%	101	100%

MODALITY	Grades 2 & 3		Grades 4 & 5		Grades 2 - 5	
	#	%	#	%	#	%
VISUAL	19	49	19	49	38	49
AUDITORY	8	20	3	8	11	14
KINESTHETIC	4	10	1	3	5	6
MIXED (V-A)	3	8	5	12	8	10
MIXED (V-K)	1	3	8	20	9	12
MIXED (A-K)	2	5	1	3	3	4
NONE (V-A-K)	2	5	2	5	4	5
TOTAL	39	100%	39	100%	78	100%

It can be noted that almost half of the total school population showed strength in the visual modality, that the second strength was auditory, that mixed visual-auditory and mixed visual-kinesthetic were stronger than kinesthetic, and that the proportion of visual to auditory to kinesthetic to mixed visual-kinesthetic to mixed auditory-kinesthetic to no-strength was about 10:3:2:2:1:1:1.

A goodness-of-fit test indicated that these observed strengths are significant for the school as a whole and that those for grades 2-5 are not significantly different from those of the school as a whole.

It was found that modality strength is independent of grade level when upper grades are compared to lower grades. That is, modality strength for students in the grades 2-5 did not depend on whether they were in grades 2, 3 or in grades 4, 5.

Insofar as sex is concerned the modality strengths for grades 2-5 were independent of this characteristic. Thus, the boys exhibited about the same strengths as the girls.

When the ESS total scores were divided into two parts - upper and lower - modality strength was independent of such classification. When the ESS scores were divided into three parts--upper, middle, lower--and when the weakest modalities were combined for statistical purposes, it was found that modality strength is still independent of reading ability--that is, of ESS score classification.

Finally, it should be noted that three of the very highest ESS scores (at least the top in each of grades 2-5) were those of students whose strongest modality was visual. Three of the very lowest ESS scores (one from each class) also were associated with a stronger visual modality. This fact is, of course, of no statistical significance since the samples considered were so small; for a large enough sample, one would expect

about half preferring the visual modality. It is mentioned here to stress the point that knowing a child's modality strength aids in no way in estimating his reading ability.

In summary, the major finding of this study was that a modality strength was exhibited by the students of Butcher school. The second major contribution of this study was the complete list of modality strengths for all the individuals in the school. This list is given with the data of Appendix I.

First grade

Student	Percent Correct On Modality			Modality Strength	Sex
	V	A	K		
1	17	40	43	AK	M
2	25	37	37	AK	M
3	42	35	23	V	M
4	36	35	28	VA	F
5	43	23	33	V	F
6	22	36	41	K	M
7	49	29	22	V	M
8	33	39	27	A	M
9	56	18	26	V	F
10	64	27	9	V	F
11	40	34	26	V	M
12	39	41	20	VA	M
13	27	43	30	A	F
14	45	30	25	V	F
15	40	38	22	VA	M
16	37	38	25	VA	F
17	30	39	30	A	M
18	26	42	32	A	F
19	35	41	24	A	M
20	53	26	21	V	M
21	48	25	27	V	F
22	37	26	37	VK	F
23	35	27	38	VK	M

Second grade

Student	ESS total score	Percent correct			Modality strength	sex
		V	A	K		
1	541	49	30	20	V	M
2	530	44	37	19	V	F
3	520	28	29	43	K	F
4	505	45	29	25	V	F
5	499	33	39	27	A	F
6	493	36	35	29	VA	F
7	493	44	25	30	V	F
8	488	54	27	19	V	F
9	478	36	44	20	A	M
10	473	48	33	19	V	M
11	460	43	33	24	V	M
12	446	26	45	29	A	M
13	444	48	12	40	V	M
14	433	43	37	20	V	F
15	429	51	32	17	V	F
16	429	39	22	39	VK	M
17	429	52	19	29	V	F
18	425	41	47	12	A	F
19	397	32	28	40	K	M
20	392	26	43	30	A	M
21	380	47	28	25	V	M
22	377	23	40	37	AK	M

Third grade

Student	ESS total score	Percent correct			Modality strength	sex
		V	A	K		
1	566	31	38	31	A	F
2	566	43	21	36	V	M
3	556	40	38	22	VA	M
4	556	40	31	29	V	F
5	540	29	35	35	AK	M
6	527	49	24	27	V	M
7	511	46	27	27	V	F
8	507	32	32	35	VAK	F
9	507	25	42	33	A	F
10	503	71	15	14	V	M
11	499	49	23	28	V	M
12	496	20	28	52	K	F
13	489	29	43	28	A	F
14	470	32	34	34	VAK	F
15	461	33	37	30	VA	M
16	457	29	17	54	K	M
17	438	52	22	26	V	M

Fourth grade

Student	ESS total score	Percent correct			modality strength	sex
		V	A	K		
1	600	43	35	22	V	F
2	600	37	39	24	VA	F
3	589	42	24	34	V	M
4	567	25	47	28	A	M
5	558	41	21	38	VK	M
6	552	45	30	25	V	F
7	541	39	22	39	VK	M
8	541	33	33	34	VAK	M
9	538	45	31	24	V	F
10	535	40	18	42	VK	M
11	532	52	19	29	V	M
12	529	43	40	17	VA	F
13	523	36	33	31	VA	M
14	515	41	27	32	V	M
15	505	35	25	37	VK	M
16	498	49	34	17	V	M
17	495	36	33	31	VA	F
18	495	31	41	28	A	M
19	495	44	28	28	V	M
20	493	39	32	28	V	M
21	493	45	37	18	V	M
22	485	44	35	21	V	F
23	454	48	21	31	V	M
24	430	52	33	15	V	M

Fifth grade

Student	ESS total score	Percent correct			Modality strength	sex
		V	A	K		
1	619	32	20	48	K	F
2	613	47	24	29	V	M
3	595	42	18	40	VK	M
4	595	27	35	38	AK	M
5	584	35	32	33	VAK	M
6	575	45	25	30	V	F
7	571	42	32	26	V	F
8	552	37	30	33	VK	F
9	548	39	37	24	VA	M
10	521	38	24	38	VK	M
11	505	53	24	23	V	M
12	498	56	18	26	V	F
13	495	35	43	22	A	F
14	493	38	27	35	VK	M
15	468	42	33	25	V	F

STATISTICAL TESTS

Test 1.

Null hypothesis: There is no significant modality strength displayed by the total population of grades 1 through 5.

Let V= modality 1, A= modality 2, K= modality 3, VA= modality 4, VK= modality 5, AK= modality 6, and VAK= modality 7.

Let P_i denote the proportion of the population showing strength in modality i .

The null hypothesis becomes: $H_0: P_i = 1/7 = .143$

Using a Chi-square goodness-of-fit test, the test statistic is $Q = \sum_{i=1}^k \frac{(N_i - np_i)^2}{np_i}$

where N_i = the number showing strength in modality i

$n = 101$, the total number in the population

$k = 7$

$$\begin{aligned}
 Q &= \frac{(47-14.443)^2}{14.443} + \frac{(16-14.443)^2}{14.443} + \frac{(6-14.443)^2}{14.443} + \frac{(12-14.443)^2}{14.442} + \\
 &\quad \frac{(11-14.443)^2}{14.443} + \frac{(5-14.443)^2}{14.443} + \frac{(4-14.443)^2}{14.443} \\
 &= \frac{1060.9 + 2.5 + 71.0 + 5.9 + 11.7 + 88.9 + 108.7}{14.443} = \frac{1349.6}{14.443} = 93.4
 \end{aligned}$$

Since Q has a Chi-square distribution with $K-1=6$ degrees of freedom, if H_0 were true, then Q would be less than 18.55 99.5% of the time.

Since $Q = 93.4$, H_0 must be rejected.

Conclusion: The evidence strongly supports the conclusion that there is modality strength exhibited by the population of the grades 1-5.

The actual proportions of the population of grades 1-5 showing strengths in modalities are given in the following table:

Modality strength	Proportion of population
V	.46
A	.16
K	.06
VA	.12
VK	.11
AK	.05
VAK	.04

Test 2.

Null hypothesis: There is no significant modality strength displayed by the total population of grades 2 through 5.

modality 1 = V; modality 2 = A, modality 3 = K, modality 4 = VA,

modality 5 = VK, modality 6 = AK, modality 7 = VAK

P_i = proportion of the population of grades 2-5 showing strength in modality i . $H_0: P_i = 1/7 \approx .143$

Using a Chi-square goodness-of-fit test, the test statistic is $Q = \sum_{i=1}^k \frac{(N_i - np_i)^2}{np_i}$

where N_i denotes the number showing strength in modality i , $k=7$, and $n=78$.

$$\begin{aligned}
 Q &= \frac{(38-11.15)^2}{11.15} + \frac{(11-11.15)^2}{11.15} + \frac{(5-11.15)^2}{11.15} + \frac{(8-11.15)^2}{11.15} + \frac{(9-11.15)^2}{11.15} \\
 &+ \frac{(3-11.15)^2}{11.15} + \frac{(4-11.15)^2}{11.15} = \frac{720.9 + .02 + 37.8 + 9.9 + 4.6 + 66.4 + 51.1}{11.15} \\
 &= \frac{890.7}{11.15} = 79.9
 \end{aligned}$$

Again, for a Chi-square distribution with $k-1=6$ degrees of freedom, 99.5% of the time Q would be less than 18.55 if H_0 were true.

Since $Q \approx 79.9$, we must reject H_0 .

Conclusion: There is significant modality strength displayed by the total population of grades 2 through 5.

The actual proportions favoring the various modalities are recorded here.

Modality strength

Proportion of population

V	.487
A	.141
K	.064
VA	.103
VK	.115
AK	.038
VAK	.051

Test 3.

Null hypothesis: The modality strengths displayed by grades 2-5 are not significantly different from those displayed by grades 1-5.

Let P_i denote the proportion of the population of grades 2-5 preferring modality i where modality i is as defined before.

The known proportions for grades 1-5 are .46, .16, .06, .12, .11, .05, and .04, successively. Hence, the null hypothesis becomes:

$$H_0: P_1 = .46, P_2 = .16, P_3 = .06, P_4 = .12, P_5 = .11, P_6 = .05, P_7 = .04$$

The test statistic is $Q = \sum_{i=1}^K \frac{(N_i - nP_i)^2}{nP_i}$

Where N_i denotes the number of those in grades 2-5 showing strength in modality i , and $n = 78$, and $K = 7$.

$$Q = \frac{(38-35.9)^2}{35.9} + \frac{(11-12.5)^2}{12.5} + \frac{(5-4.7)^2}{4.7} + \frac{(8-9.4)^2}{9.4} + \frac{(9-8.6)^2}{8.6} + \frac{(3-3.9)^2}{3.9} + \frac{(4-3.1)^2}{3.1}$$

$$= .1228 + .18 + .0191 + .2085 + .0186 + .2077 + .2613 = 1.018$$

The critical value of a Chi-square distribution with 6 degrees of freedom is 10.64 at the 10% significance level ...

Since $Q = 1.018$, we can not reject H_0 .

Conclusion: The modality strengths displayed by grades 2-5 are not significantly different from those displayed by grades 1-5.

Test 4.

Null hypothesis: The modality strengths displayed by the population of grades 2-5 are independent of whether lower grade (grades 2,3) or upper grade (grades 4,5).

Using a Chi-square test for independence, the numbers in the cells are the observed frequencies and those in parentheses are the expected frequencies when the null hypothesis is true.

grade level	modality strengths							totals
	V	A	K	VA	VK	AK	VAK	
2-3	19 (19)	8 (5.5)	4 (2.5)	3 (4)	1 (4.5)	2 (1.5)	2 (2)	39
4-5	19 (19)	3 (5.5)	1 (2.5)	5 (4)	8 (4.5)	1 (1.5)	2 (2)	39
totals	38	11	5	8	9	3	4	78

Test statistic: $\chi^2 = \sum_{i=1}^R \sum_{j=1}^C \frac{(N_{ij} - E_{ij})^2}{E_{ij}}$ where R = number of rows = 2
 C = number of columns = 7
 N_{ij} is observed cell frequency
 E_{ij} is expected cell frequency

The distribution is a Chi-square with $(7-1)(2-1) = 6$ degrees of freedom. The critical value at the 10% significance level is 10.64.

$$\begin{aligned} \chi^2 &= \frac{(19 - 19)^2}{19} + \frac{(8 - 5.5)^2}{5.5} + \frac{(4 - 2.5)^2}{2.5} + \frac{(3 - 4)^2}{4} + \frac{(1 - 4.5)^2}{4.5} + \frac{(2 - 1.5)^2}{1.5} + \\ &\quad \frac{(2 - 2)^2}{2} + \frac{(19 - 19)^2}{19} + \frac{(3 - 5.5)^2}{5.5} + \frac{(1 - 2.5)^2}{2.5} + \frac{(5 - 4)^2}{4} + \frac{(8 - 4.5)^2}{4.5} + \\ &\quad \frac{(1 - 1.5)^2}{1.5} + \frac{(2 - 2)^2}{2} = 1.135 + .9 + .25 + 2.7 + .16 + 1.14 + .9 + .25 + \\ &\quad 2.7 + .17 = 10.3 \end{aligned}$$

Conclusion: Since $\chi^2 = 10.3 < 10.64$, do not reject H_0 .

There is not sufficient evidence to reject the null hypothesis. Thus we conclude that modality strength is independent of grade level.

Test 5.

Null hypothesis: In grades 2-5 the modality strength is independent of sex.

sex	modality strengths							totals
	V	A	K	VA	VK	AK	VAK	
male	21 (21.9)	5 (6.35)	2 (2.9)	4 (4.6)	8 (5.2)	3 (1.73)	2 (2.3)	45
female	17 (16)	6 (4.6)	3 (2.1)	4 (3.4)	1 (3.8)	0 (1.26)	2 (1.7)	33
totals	38	11	5	8	9	3	4	78

$$\text{Test statistic: } Q = \sum_{i=1}^R \sum_{j=1}^C \frac{(N_{ij} - E_{ij})^2}{E_{ij}}$$

Where N_{ij} denotes the number of observations in cell ij and E_{ij} denotes the expected frequency for that cell when the null hypothesis is true.

The chi-square distribution is a good approximation to the actual distribution of Q if each cell expected frequency is equal to or greater than 5 and is still satisfactory if each is equal to or greater than 1.5." DeGroot. P.439. Since the expected frequency of cell 2, 6 is

$$\begin{aligned} \text{less than 1.5, we combine modalities AK and VAK...resulting in two rows} \\ \text{and six columns. With this modification, } Q = & \frac{(21-21.9)^2}{21.9} + \frac{(5-6.35)^2}{6.35} \\ & + \frac{(2-2.9)^2}{2.9} + \frac{(4-4.6)^2}{4.6} + \frac{(8-5.2)^2}{5.2} + \frac{(5-4.03)^2}{4.03} + \frac{(17-16)^2}{16} + \frac{(6-4.6)^2}{4.6} \\ & + \frac{(3-2.1)^2}{2.1} + \frac{(4-3.4)^2}{3.4} + \frac{(1-3.8)^2}{3.8} + \frac{(2-2.96)^2}{2.96} = 5.7168 \end{aligned}$$

The critical value for a Chi-square distribution with five degrees of freedom at the 10% level of significance is 9.236.

Since $Q = 5.7168 < 9.236$, we have insufficient evidence to support rejection of H_0 . Conclusion: Do not reject H_0 . Hence in grades 2-5 modality preference is independent of sex in the sense that the given evidence does not suggest otherwise.

Test 6.

Null hypothesis: Modality strength in grades 2-5 is independent of level of reading ability.

Reading ability	modality strengths							totals
	V	A	K	VA	VK	AK	VAK	
upper half	19 (19)	5 (5.5)	2 (2.5)	4 (4.02)	4 (4.5)	2 (1.5)	3 (1.9)	39
lower half	19 (19)	6 (5.5)	3 (2.5)	4 (4.02)	5 (4.5)	1 (1.5)	1 (1.9)	39
totals	38	11	5	8	9	3	4	78

Here, reading ability is indicated by the total ESS score.

Test statistic: $Q = 0 + .045 + .1 + 0 + .055 + .166 + .637 + 0 + .045 + .1$
 $+ 0 + .055 + .166 + .426 = 1.795$

Critical value for a chi-square distribution with six degrees of freedom and a significance level of 10% is 10.64.

Conclusion: Do not reject H_0 . The evidence does not support a rejection of this hypothesis. We conclude that in grades 2-5, the modality strength is independent of whether the student's reading ability as indicated by his total ESS score is in the top half or the lower half.

Test 7.

Null hypothesis. Modality strength in grades 2-5 is independent of level of reading ability (in terms of upper scores, middle scores and lower scores).

In order to satisfy the requirement that the expected cell frequencies be at least 1.5, we have reclassified the modalities as follows.

Reading ability	modality strength					totals
	V	A	VA	VK	other	
upper third	11 (12.66)	3 (3.66)	3 (2.68)	3 (2.99)	6 (3.98)	26
middle third	14 (12.66)	3 (3.66)	3 (2.68)	4 (2.99)	2 (3.98)	26
lower third	13 (12.66)	5 (3.66)	2 (2.68)	2 (2.99)	4 (3.98)	26
totals	38	11	8	9	12	78

Again reading ability is as indicated by the total ESS score. The true proportions used with the above reclassification of modalities are:

.487 for V, .141 for A, .103 for VA, .115 for VK and .153 for others.

The critical value of a Chi-square with $(5-1)(3-1) = 8$ degrees of freedom at the 10% significance level is 13.361.

The test statistic is $\chi^2 = .2176 + .1190 + .0382 + .0 + 1.025$
 $+ .1418 + .1190 + .0382 + .3411 + .985$
 $+ .0091 + .4906 + .1725 + .3277 + .0001$
 $= 4.025$

Conclusion: Since $\chi^2 = 4.025 < 13.361$, there is not enough evidence shown to support a rejection of H_0 . Hence we conclude that modality preference is indeed independent of reading ability.

Test 8.

Null hypothesis. If every student of grades 2-5 is classified as type I if his visual percentage is at least 5 points higher than his auditory percentage, as type II if his visual percentage is at least 5 points lower than his auditory percentage, and as type III otherwise, then this classification is independent of reading ability as measured by total ESS scores.

Reading ability	Classification			Total
	Type I	Type II	Type III	
Upper	15 (16.3)	5 (5)	6 (4.7)	26
Middle	18 (16.3)	4 (5)	4 (4.7)	26
Lower	16 (16.3)	6 (5)	4 (4.7)	26
TOTALS	49	15	14	78

$$\begin{aligned}\text{Test statistic: } Q &= .104 + 0 + .36 + .18 + .2 + .104 + .006 + .07 + .104 \\ &= 1.13\end{aligned}$$

The critical value for a Chi-square distribution with $(3-1)(3-1) = 4$ degrees of freedom at the 10% significance level is 7.779.

Since $Q = 1.13 < 7.779$, do not reject H_0 . Hence the modality preferences as described above are independent of reading ability.

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